Howe Sound Juvenile Prawn, *(Pandalus platyceros)*, Survey with a Review of Estuaries as Shrimp and Prawn Nursery Habitats

N. A. Sloan

Department of Fisheries and Oceans
Fisheries Research Branch
Pacific Biological Station
Nanaimo, British Columbia V9R 5K6

May 1987

Canadian Manuscript Report of Fisheries and Aquatic Sciences No. 1936

Fisheries and Oceans Pêches et Océans

Canada

Canadian Manuscript Report of Fisheries and Aquatic Sciences

Manuscript reports contain scientific and technical information that contributes to existing knowledge but which deals with national or regional problems. Distribution is restricted to institutions or individuals located in particular regions of Canada. However, no restriction is placed on subject matter, and the series reflects the broad interests and policies of the Department of Fisheries and Oceans, namely, fisheries and aquatic sciences.

Manuscript reports may be cited as full publications. The correct citation appears above the abstract of each report. Each report is abstracted in *Aquatic Sciences and Fisheries Abstracts* and indexed in the Department's annual index to scientific and technical publications.

Numbers 1–900 in this series were issued as Manuscript Reports (Biological Series) of the Biological Board of Canada, and subsequent to 1937 when the name of the Board was changed by Act of Parliament, as Manuscript Reports (Biological Series) of the Fisheries Research Board of Canada. Numbers 901–1425 were issued as Manuscript Reports of the Fisheries Research Board of Canada. Numbers 1426–1550 were issued as Department of Fisheries and the Environment, Fisheries and Marine Service Manuscript Reports. The current series name was changed with report number 1551.

Manuscript reports are produced regionally but are numbered nationally. Requests for individual reports will be filled by the issuing establishment listed on the front cover and title page. Out-of-stock reports will be supplied for a fee by commercial agents.

Rapport manuscrit canadien des sciences halieutiques et aquatiques

Les rapports manuscrits contiennent des renseignements scientifiques et techniques qui constituent une contribution aux connaissances actuelles, mais qui traitent de problèmes nationaux ou régionaux. La distribution en est limitée aux organismes et aux personnes de régions particulières du Canada. Il n'y a aucune restriction quant au sujet; de fait, la série reflète la vaste gamme des intérêts et des politiques du ministère des Pêches et des Océans, c'est-à-dire les sciences halieutiques et aquatiques.

Les rapports manuscrits peuvent être cités comme des publications complètes. Le titre exact paraît au-dessus du résumé de chaque rapport. Les rapports manuscrits sont résumés dans la revue *Résumés des sciences aquatiques et halieutiques*, et ils sont classés dans l'index annuel des publications scientifiques et techniques du Ministère.

Les numéros 1 à 900 de cette série ont été publiés à titre de manuscrits (série biologique) de l'Office de biologie du Canada, et après le changement de la désignation de cet organisme par décret du Parlement, en 1937, ont été classés comme manuscrits (série biologique) de l'Office des recherches sur les pêcheries du Canada. Les numéros 901 à 1425 ont été publiés à titre de rapports manuscrits de l'Office des recherches sur les pêcheries du Canada. Les numéros 1426 à 1550 sont parus à titre de rapports manuscrits du Service des pêches et de la mer, ministère des Pêches et de l'Environnement. Le nom actuel de la série a été établi lors de la parution du numéro 1551.

Les rapports manuscrits sont produits à l'échelon régional, mais numérotés à l'échelon national. Les demandes de rapports seront satisfaites par l'établissement auteur dont le nom figure sur la couverture et la page du titre. Les rapports épuisés seront fournis contre rétribution par des agents commerciaux.

Canadian Manuscript Report of
Fisheries and Aquatic Sciences No. 1936

May 1987

HOWE SOUND JUVENILE PRAWN, (*Pandalus platyceros*), SURVEY WITH A REVIEW OF ESTUARIES AS SHRIMP AND PRAWN NURSERY HABITATS

by

N. A. Sloan

Department of Fisheries and Oceans
Fisheries Research Branch
Pacific Biological Station
Nanaimo, British Columbia V9R 5K6

88-00942/

(c) Minister of Supply and Services Canada 1987

Cat. No. Fs 97-4/1936E ISSN 0706-6473

Correct citation for this publication:

Sloan, N. A. 1987. Howe Sound juvenile prawn, Pandalus platyceros, survey with a review of estuaries as shrimp and prawn nursery habitats. Can. MS Rep. Fish. Aquat. Sci. 1936: 25 p.

ABSTRACT

Sloan, N. A. 1987. Howe Sound juvenile prawn, Pandalus platyceros, survey with a review of estuaries as shrimp and prawn nursery habitats. Can. MS Rep. Fish. Aquat. Sci. 1936: 25 p.

This report recounts the results of a largely shallow-water trap survey for juveniles of the protandric hermaphrodite prawn, Pandalus platyceros, in Howe Sound in August 1986. Juveniles (preadult males) formed 10% of the 2493 prawns taken in 36 sets. Catches of juveniles were patchy in sets to 60 m and mean catches were highest in the 46-60 m depth stratum. Juvenile size did not vary in a clearly depth-related pattern but the mean size of mature males was significantly smaller in the shallowest sets compared to those taken in deeper sets. These results are discussed in relation to the literature on juvenile P. platyceros habitat occupation. A short review of the role of estuaries, which include fjordic inlets, as nursery grounds for pandalid and penaeid shrimps is included.

RESUME

Sloan, N. A. 1987. Howe Sound juvenile prawn, Pandalus platyceros, survey with a review of estuaries as shrimp and prawn nursery habitats. Can. MS Rep. Fish. Aquat. Sci. 1936: 25 p.

Le présent rapport porte sur les résultats d'un relevé à la trappe de la crevette tachée (Pandalus platyceros) hermaphrodite protérandre effectué principalement dans les eaux peu profondes de la baie Howe en août 1986. Les juvéniles (mâles pré-adultes) représentaient 10% des 2 493 crevettes capturées dans 36 mouillages. Dans les mouillages effectués jusqu'à 60 m, les captures de juvéniles étaient inégales tandis que les plus importantes prises moyennes ont été observées dans la strate de profondeur allant de 46 à 60 m. La taille des juvéniles ne variait pas selon un régime défini en fonction de la profondeur mais la taille moyenne des mâles adultes était nettement inférieure dans les mouillages en eau peu profonde par rapport à ceux capturés en eau profonde. Les résultats sont étudiés à la lumière des données publiées sur l'habitat fréquenté par les juvéniles de P. platyceros. Est aussi incluse un court examen du rôle des estuaires, y compris les inlets de type fjord, comme aires de croissance pour les crevettes des familles Pandalidae et Penaeidae.

INTRODUCTION

The early life history of Pandalus platyceros Brandt has received little attention since Berkley's (1930) studies. Information on juvenile prawn life history from British Columbia populations is largely anecdotal (Berkley 1930; Butler 1964) although there are some observations on juvenile prawns from Alaska (Barr 1970, 1971, 1973).

In British Columbia female prawns are 3 to 4 years old and bear eggs from October to March (Butler 1964). Females may spawn more than once in their lives (Rensel and Prentice 1978). Butler (1970) speculated that spawning occurs over rocky substrates at depths > 73 m. Fertilized eggs are incubated for approximately 5 months and hatching occurs between late March and early April within an unknown depth range, and possibly during nighttime (Berkley 1930).

Descriptions of the larval stages of the protendric hermaphrodite P. platyceros were first made from nature (Berkley 1930), later revised following laboratory culture of fertilized eggs from known parents (Prince and Chew 1972) and were recently reviewed by Haynes (1985). There are five larval stages, stages I-IV being zoea and stage V being a megalopa, and five juvenile stages prior to maturation into males. Haynes (1985) believes that pandalid larvae "probably influence the direction and extent of their dispersal" by their vertical swimming ability which enables movement between differing water masses which transport larvae. Berkley (1930) recorded stage I and II larvae from deep-water (approximately 100 m) whereas larval stages IV, and VI (= stage V megalope: Haynes 1985) were found in < 6 m depth. Prawn larvae can live 11 to 13 days on stored yolk with no food, although they also have the behavioral flexibility to feed immediately after hatching in the laboratory (Price and Chew 1972). The shallow-water phase of late stage larvae, including metamorphosis into the juvenile phase, is speculated to occur in summer (Butler 1964). Some pandalid species larvae have a vertical diel migration to shallow-water locations (< 15 m) at night from a daytime depth of 30-60 m (Haynes 1985).

Juvenile prawn apparently share their shallow-water habitat with coonstripe (P. danae) and humpback (P. hypsinotus) shrimp (Haynes 1985). Butler (1964) speculated that in late summer-autumn of their first year prawn "habitate shallow water bays and inlets" to feed on detritus, generated by plankton and macroalgae, as well as on small crustaceans. Butler went on to propose that late in their first year prawn migrate to deeper water to feed on "epifauna of rocky bottoms and . . . detritus in mud" to maintain rapid growth. Thus, by one year of age, juvenile prawn allegedly migrate away from shore and can be found to approximately 110 m (Berkley 1930; Butler 1964). By 1.5 years of age, individual prawn have become mature males and have recruited to the fishery. Adult prawn may undergo diel vertical migration, being found at shallower depths at night and at deeper depths during the day (Chew et al. 1974; Boutillier 1986) although Jamieson and Pikitch (pers. comm.) suggest this may not be as prevelent as previously thought.

I report here on a largely shallow-water survey in the mouth of Howe Sound in August for juvenile prawn. The object was to fish special traps designed to retain small prawn in order to locate the alleged shallow-water habitats used by prawn in their first summer. Secondly, a short review on the role of estuaries as nursery areas for prawn and shrimp species worldwide is provided. The extensive knowledge on penaeids is used as an example of how knowledge of juvenile life history stages can be useful in predicting adult stock status.

MATERIALS AND METHODS

Trap sampling occurred in 36 sets among a group of islets at the mouth of Howe Sound and along the southern shores of Gambier Island (Fig. 1). Four types of traps were used as described in Table 1. The date, location, depth, fishing effort, and catch in the trap sampling are listed in Table 2. Ten to twenty one traps were attached at 5 m intervals along groundlines set to 87 m:

Depth range (m)	Sets (n)
0-15	17
16-30	8
31-45	4
46-60	4
61-75	2
76-90	1

Each trap was baited with a 100 g can of sardines packed in oil and punctured twice. Baits were usually used only once. Traps were usually set before midday and mean soak time was 25.4 h. Captured prawn were counted, sexed (using endopod developement on the second pleopod, see Butler 1980), their carapace length (CL) measured (posterior orbital rim to median dorsal carapace edge) and retained. Most of the fishing was done with the "Pardiac" traps as the others were ineffective in capturing prawns (Table 2).

The carapace lengths of juvenile (sex class 0) and males (sex class 1) prawn were divided according to four arbitrary depth range levels (6-15,19-28,37-39,50-59 m). These data sets were analyzed to determine whether they met the normality assumptions for an ANOVA. Size frequencies were normally distributed. ANOVA of untransformed size data at four depth levels within two sex classes were run. A posteriori Tukey multiple comparison tests (Zar 1984) were conducted to identify which depth-related size frequencies varied significantly within the sex classes.

Beach seining was conducted at six sites during low tides, through four different sea grass beds on sandy-gravel beaches between Langdale and Gibsons (Fig. 1). The beach seine was 3 m deep and 12 m long with a 4 m

central panel of 1.0 cm stretch, green braided nylon mesh and two, 4 m end panels of green braided nylon 3.0 cm stretch mesh.

Three SCUBA dives were completed in the southeast Popham Island area (site of trap set 6 in Fig. 1) to observe microhabitat utilization by young prawn and their behaviour in traps.

RESULTS

Size frequencies of the juvenile, male, and transition and female combined are shown in Figure 2. Only 21 of the 2493 prawn caught (0.8%) were transition/females, whereas mature males represented 89.2%. Most of the males were sublegal in size (Fig. 2).

Catches of juvenile prawns shown in Table 2 demonstrated marked variability, irrespective of depth:

Depth strata (m)	Total sets	Total juveniles	Sets in which caught	Juveniles according to successful set $\bar{x}$	Juveniles according to successful set range
0-15	17	90	6	5.3	1-48
16-30	8	69	6	8.6	1-45
31-45	4	9	1	2.3	-
46-60	4	77	4	19.3	1-49
61-75	2	4	2	4.0	1-3
76-90	1	0	-	-	-

Figure 3 illustrates the size frequencies of juvenile (sex class 0) prawn taken from sets according to four arbitrary depth strata. The ANOVA results listed in Table 3 show that there was significant difference between the mean juvenile prawn sizes by depth. An *a posteriori* Tukey comparison test revealed that the mean size of 6-15 m depth level prawn were significantly smaller than those of 19-28 m and 50-59 m depth level prawn ($p<0.05$).

Figure 4 illustrates the size frequencies of males taken from the four different depth strata. The data were tested as above and the ANOVA results in Table 3 show that there was a significant difference between the mean 1-class prawn sizes by depth. A Tukey comparison test showed that the 6-15 m depth level prawn were significantly smaller in size compared to those of all other depth strata ($p<0.05$).

No prawn were taken in the low tide beach seining through the sea grass (*Zostera*) beds. Diving along the trap lines yielded no prawn observations because of poor visibility.

DISCUSSION

The patchy distribution of juvenile prawn in Howe Sound in August to at least 60 m depth demonstrates that they are not restricted to shallow waters. Trapping did not reveal a preference for shallow habitats, as reported from *in situ* observations of juvenile prawn in Alaska (Barr 1971, 1973), although some juveniles certainly did occupy shallow habitats. Mean size of the 6-15 m depth level juveniles was smaller than those of the 19-28 m and 50-59 m depth levels, but not the 37-39 m depth level juveniles. This lack of a consistent gradation of depth-related sizes could indicate mixing and appreciable vertical mobility of juvenile prawn. Thus, juveniles may not have a marked habitat preference within the top 60 m in Howe Sound. This depth range is nonetheless generally shallower than that occupied by adults in the majority of the commercial fishery. If anything, overnight trapping should have favored the shallow-water abundance of prawn as they may have a diel migration pattern to shallow-water at night (Chew et al. 1974; Boutillier 1986). Boutillier (1986) caught significantly larger prawn in shallower sets in Howe Sound but there was a much higher proportion of legal-sized prawn than in this study probably due in part to his using commercial traps with 2.8 cm stretch mesh.

The fact that males, most of which were of sublegal size (<30 mm CL), were significantly smaller at the 6-15 m depth level than all other levels may indicate that they migrate deeper as they grow. This is a common characteristic in pandalids which tend to occupy generally shallower waters prior to offshore, deeper-water occupation for sex change and spawning as mature females. Table 4 lists the depth-related/inshore-offshore characteristics reported for some pandalid species. In most of the species late larvae (= after stage IV) occur separately from adults in relatively shallower water, but not always more inshore. Haynes (1983) stated that concentrations of late stage larvae may not necessarily indicate areas of settlement because transition to the last larval stage (V or megalopa) has little effect on their mobility (swimming ability). None of the B.C. species are associated with shallow estuaries, although *P. danae*, *P. hypsinotus*, *P. dispar* and prawns do occur in fjordic inlets which are specialized, albeit deep, estuaries (Farmer and Freeland 1983). A good example of the flexibility of pandalid life histories can be seen in *P. montagui* (Table 4) in which different English coast populations vary from strictly offshore to a combination of offshore and estuarine. Along the east coast of North America the life history of *P. montagui* also varies with location (Stevenson and Pierce 1985).

Beach seining through sea grass (*Zostera*) at low tide yielded no prawn. *Pandalus kessleri* in Hokkaido, Japan is associated with sea grass as larvae, and these have been suggested to be juvenile nursery areas (Mizushima 1985). Barr (1973) found that juvenile prawn were associated with macroalgae in the shallow subtidal at night. We did not beach seine at night, nor could we find suitable rocky ground for beach seining through macroalgae during the day.

The life histories of penaeid shrimp are much better understood than those of pandalids, probably because they comprise much larger fisheries worldwide. The general pattern of penaeid life histories is closely tied to inshore estuaries and lagoons (Garcia and LeReste 1981). Adults spawn in saline offshore waters and hatching of the demersal eggs usually occurs within 24 h. Feeding begins at the sixth larval stage and another five larval stages occur at sea after which young postlarvae enter estuarine nursery grounds. In these shallows the postlarvae settle on the bottom, in areas usually associated with vegetation, and growth occurs to the juvenile stage. After 2 to 6 months in estuaries, the young shrimp move into deeper water which leads to seaward migration to offshore spawning grounds and completion of the 12 month life cycle. Penaeids are discussed here as an example because the well-being of inshore areas (i.e. estuaries) and their attendant vegetation has been directly related to commercial yields of shrimp (Kutkuhn 1966; Turner 1977; Weinstein 1979). The immense progress in penaeid shrimp biology as reviewed in part in Table 5 demonstrates a level of understanding, particularly in the USA and Australia, which could serve as a model for future pandalid work. As the knowledge of inshore habitat needs of B.C. prawns improves, then the production capacity of inlets and bays will be better understood. Our understanding of the life histories of panalids requires much work.

ACKNOWLEDGMENTS

I thank the crew of the M/V Caligus, S. Head, and W. Moore for field support. C. Fort and C. Lauridson aided in the data analysis, J. Boutillier and G. Jamieson kindly reviewed early drafts. J. Marlaive of the Vancouver Public Aquarium discussed many aspects of the project with me and supplied volunteer buddy divers.

REFERENCES

Allen, J. A. 1959. On the biology of Pandalus borealis Kroyer, with reference to a population off the Northumberland coast. J. Mar. Biol. Ass. U.K. 38: 189-220.

Allen, J. A. 1963. Observations on the biology of Pandalus montagui (Crustacea: Decapoda). J. Mar. Biol. Ass. U.K. 43: 665-682.

Barr, L. 1970. Methods of estimating the abundance of juvenile spot shrimp in a shallow nursery area. Proc. Nat. Shellfish Assoc. 60: 12.

Barr, L. 1971. Methods of estimating the abundance of juvenile spot shrimp in a shallow nursery area. Trans. Am. Fish. Soc. 100: 781-786.

Barr, L. 1973. Studies of spot shrimp, Pandalus platyceros, at Little Port Walter, Alaska. Mar. Fish. Rev. 35: 65-66.

Berkley, A. F. 1930. The post-embryonic development of the common pandalids of British Columbia. Contrib. Can. Biol. (N.S.) 6: 79-163.

Boutillier, J. A. 1986. Fishing effort standardization in the British Columbia prawn (Pandalus platyceros) trap fishery. In: G. S. Jamieson and N. Bourne [eds.]. North Pacific workshop on stock assessment and management of invertebrates. Can. Spec. Publ. Fish. Aquat. Sci. 92: 176-181.

Butler, T. H. 1964. Growth, reproduction, and distribution of pandalid shrimps in British Columbia. J. Fish. Res. Board Can. 21: 1403-1452.

Butler, T. H. 1970. Synopsis of biological data on the prawn Pandalus platyceros Brandt, 1851. FAO Fish. Synopsis No. 95: 1289-1315.

Butler, T. H. 1980. Shrimps of the Pacific coast of Canada. Can. Bull. Fish. Aquat. Sci. 202: 280 p.

Chew, K. K., D. Holland, J. W. Wells, D. H. McKenzie, and C. K. Harris. 1974. Depth distribution and size of spot shrimp, Pandalus platyceros, trawled in Dabob Bay of Hood Canal, Washington from 1966 to 1971. Proc. Nat. Shellfish Assoc. 64: 28-32.

Cockroft, A. C. and A. McLachlan. 1986. Distribution of juvenile and adult penaeid prawns, Macropelasma africanus (Balss) in Algoa Bay. S. Afr. J. Mar. Sci. 4: 245-255.

Coles, R. G. and J. G. Greenwood. 1983. Seasonal movement and size distribution of three commercially important Australian prawn species (Crustacea: Penaeidae) within an estuarine system. Aust. J. Mar. Freshwater Res. 34: 727-743.

Coles, R. G. and W. J. Lee Long. 1985. Juvenile prawn biology and the distribution of seagrass prawn nursery grounds in the southeastern Gulf of Carpentaria. pp. 55-60. In: P. C. Rothlisburg, B. J. Hill, and D. J. Staples [eds.]. Second Australian National Prawn Seminar, NPS2, Cleveland, Australia.

Farmer, D. M. and H. J. Freeland. 1983. The physical oceanography of fjords. Prog. Oceanogr. 12: 147-220.

Garcia, S. and L. LeReste. 1981. Life cycles, dynamics, exploitation and management of coastal panaeid shrimp stocks. FAO Fish. Tech. Pap. 203: 215 p.

Giles, J. H. and G. Zamora. 1973. Cover as a factor in habitat selection by juvenile brown (Penaeus aztecus) and white (P. setiferus) shrimp. Trans. Am. Fish. Soc. 102: 144-145.

Haynes, E. B. 1983. Distribution and abundance of larvae of king crab, Paralithodes camtschatica, and pandalid shrimp in the Kachemak Bay area, Alaska, 1972 and 1976. NOAA Tech. Rep. NMFS SSRF-765: 64 p.

Haynes, E. B. 1985. Morphological development, identification, and biology of larvae of Pandalidae, Hippoloytidae, and Crangonidae (Crustacea, Decapoda) of the northern north Pacific Ocean. Fish. Bull. 83: 253-288.

Hughes, D. A. 1966. Investigations of the 'nursery areas' and habitat preferences of juvenile penaeid prawns in Mozambique. J. Appl. Ecol. 3: 349-354.

Kutkuhn, J. H. 1966. The role of estuaries in the role of development and perpetuation of commercial shrimp resources. Am. Fish. Soc. Spec. Publ. 3: 16-36.

Minello, T. J. and R. J. Zimmerman. 1985. Differential selection of vegetative structure between juvenile brown shrimp (Penaeus aztecus) and white shrimp (P. setiferus), and implications in predator-prey relationships. Est. Cstl. Shelf Sci. 20: 707-716.

Mistakidis, M. N. 1957. The biology of Pandalus montagui Leach. MAFF (London) Fish. Invest. 21(4): 49 p.

Mizushima, T. 1985. Relationship between the density of the larvae of Pandalus kessleri C. and that of Zostera marina L. Monthly Rep. Hokkaido Fish. Exp. Stn. 42: 14-25. (Can. Transl. Fish. Aquat. Sci., Ottawa No. 5222, 1986).

Pearson, J. C. 1939. The early life histories of some American penaeidae, chiefly the commercial shrimp Penaeus setiferus (Linn.). Bull. U.S. Bur. Fish. 30: 73 p.

Penn, J. W. and N. Caputi. 1986. Spawning stock-recruitment relationships and environmental influences on the tiger prawn (Penaeus esculentus) fishery in Exmouth Gulf, Western Australia. Aust. J. Mar. Freshwater. Res. 37: 491-505.

Potter, I. C., J. W. Penn, and R. S. Brooker. 1986. Life cycle of the western school prawn, Metapenaeus dalli Racek, in a Western Australian estuary. Aust. J. Mar. Freshwater Res. 37: 95-103.

Price, V. A. and K. K. Chew. 1972. Laboratory rearing of spot shrimp larvae (Pandalus platyceros) and descriptions of stages. J. Fish. Res. Board Can. 29: 413-422.

Rensel, J. E. and E. F. Prentice. 1978. First record of a second mating and spawning of the spot prawn, Pandalus platyceros, in captivity. Fish. Bull. 75: 648-649.

Rothlisberg, P. C. and C. B. Miller. 1983. Factors affecting the distribution, abundance, and survival of Pandalus jordani (Decapoda, Pandalidae) larvae off the Oregon coast. Fish. Bull. 81: 455-472.

Shumway, S. E., H. C. Perkins, D. F. Shick, and A. P. Stickney. 1985. Synopsis of biological data on the pink shrimp, Pandalus borealis Kroyer, 1838. NOAA. Tech. Rep. NMFS 30: 57 p.

Staples, D. J. 1985. Modelling the recruitment processes of the banana prawn, Penaeus merguensis, in the southeastern Gulf of Carpentaria, Australia. pp. 175-184. In: P. C. Rothlisberg, B. J. Hill, and D. J. Staples [eds.]. Second Australian National Prawn Seminar, NPS2, Cleveland Australia.

Staples, D. J. and D. J. Vance. 1985. Short-term and long-term influences on the immigration of post larval banana prawns, Penaeus merguensis, into a mangrove estuary of the Gulf of Carpentaria, Australia. Mar. Ecol. Prog. Ser. 23: 15-29.

Staples, D. J., D. J. Vance, and D. S. Heales. 1985. Habitat requirements of juvenile penaeid prawns and their relationship to offshore fisheries. pp. 47-54. In: P. C. Rothlisberg, B. J. Hill, and D. J. Staples [eds.]. Second Australian National Prawn Seminar. NP52, Cleveland, Australia.

Staples, D. J. and D. J. Vance. 1986. Emigrating juvenile banana prawns Penaeus merguensis from a mangrove estuary and recruitment to offshore areas in the wet-dry tropics of the Gulf of Carpentaria, Australia. Mar. Ecol. Prog. Ser. 27: 239-252.

Stevenson, D. K. and F. Pierce. 1985. Life history characteristics of Pandalus montagui and Dichelopandalus leptocerus in Penobscot Bay, Maine. Fish. Bull. 83: 219-233.

Tom, M., A. Shlagman, and C. L. Lewinsohn. 1984. The benthic phase of the life cycle of Penaeus semisulcatus De Haan (Crustacea Decapoda) along the southeastern coast of the Mediterranean. P.S.Z.N.I.: Mar. Ecol. 5: 229-241.

Turner, R. E. 1977. Intertidal vegetation and commercial yields of panaeid shrimp. Trans. Am. Fish. Soc. 106: 411-416.

Weinstein, M. P. 1979. Shallow marsh habitats as primary nurseries for fishes and shellfish, Cape Fear River, North Carolina. Fish. Bull. 77: 339-357.

Williams, A. B. 1955. A survey of North Carolina shrimp nursery grounds. Elisha Mitchell Sci. Soc. 71: 200-207.

Young, P. C. 1978. Moreton Bay, Queensland: A nursery area for juvenile penaeid prawns. Aust. J. Mar. Freshwater Res. 29: 55-75.

Young, P. C. and S. M. Carpenter. 1977. Recruitment of postlarval penaeid prawns to nursery areas in Moreton Bay, Queensland. Aust. J. Mar. Freshwater Res. 28: 745-773.

Zimmerman, R. J., T. J. Minello, and G. Zamora. 1984. Selecting vegetated habitat by brown shrimp, Penaeus aztecus, on a Galveston Bay salt marsh. Fish. Bull. 82: 325-336.

Table 1. Characteristics of the four trap types used in the Howe Sound juvenile prawn survey.

Trap characteristics				Tunnel characteristics	
Type and structure	Dimensions (cm) top x bot. x side	Volume (l)	Mesh characteristics	n	Inside opening diameter (cm)
Round 'Pardiac' mesh-covered, 4-posted metal frame	60* x 60* x 24	68	Green braided nylon 1.0 cm stretched mesh	4	5.5
Wooden box	46 x 30 x 23	32	Black plastic mesh in tunnel, 0.6 cm stretched	1	4.5
Minnow trap galvanized wire mesh	19* x 19* x 42	12	Rigid square wire mesh with 0.6 cm sides	2	3.5
Plastic tube	8* x 8* x 75	4	Black plastic mesh in tunnels, 0.6 cm stretched	2	3.5

*Diameter

Table 2. Date, location, depth, effort, and catch of prawns from the Howe Sound juvenile prawn survey, August 1986. Sex class 0=juvenile; 1=male; 2=transition; 3=female; 4=berried female.

Set no.	Date			Location			Depth (m)		Soak	No. of traps*					Prawn catch							
															sex class (n)						Weight (kg)	
	d	m	y	Area	Sub-a	Local	Min	Max	(h)	P	B	M	T	Total	0	1	2	3	4	Total		
001	8	8	86	28	01	07	28	28	20	7	-	14	-	21	-	-	-	-	-	-	-	
002	8	8	86	28	01	07	26	28	20	15	-	2	-	17	1	-	-	-	-	1	-	
003	9	8	86	28	01	07	37	43	23	15	-	5	-	20	9	6	-	-	-	15	0.2	
004	9	8	86	28	01	07	46	52	24	15	-	5	-	20	1	-	-	-	-	1	-	
005	9	8	86	28	01	07	9	11	20	-	10	5	-	15	-	-	-	-	-	-	-	
006	10	8	86	28	01	07	7	9	43	10	-	3	2	15	-	-	-	-	-	-	-	
007	10	8	86	28	01	07	28	30	23	15	-	-	-	15	1	1	-	-	-	2	-	
008	10	8	86	28	01	07	56	59	26	15	-	-	-	15	9	108	-	3	-	120	1.6	
009	11	8	86	28	01	07	9	11	23	10	-	-	2	12	-	-	-	-	-	-	-	
010	11	8	86	28	01	07	9	9	24	15	-	-	-	15	-	-	-	-	-	-	-	
011	11	8	86	28	01	07	9	9	22	-	10	-	-	10	-	-	-	-	-	-	-	
012	11	8	86	28	01	07	61	70	20	15	-	-	-	15	1	2	-	-	-	3	-	
013	12	8	86	28	01	07	9	15	23	10	-	-	-	10	-	-	-	-	-	-	-	
014	12	8	86	28	01	07	13	15	23	-	10	-	-	10	-	-	-	-	-	-	-	
015	12	8	86	28	01	07	70	75	22	15	-	-	-	15	3	4	-	-	-	7	-	
016	12	8	86	28	01	07	13	19	24	15	-	-	-	15	-	-	-	-	-	-	-	
017	14	8	86	28	01	02	46	56	46	0	10	-	-	10	-	-	-	-	-	-	-	
018	14	8	86	28	01	01	6	8	46	15	-	-	-	15	-	12	-	-	-	12	0.2	
019	14	8	86	28	01	01	37	39	45	12	-	-	-	12	49	445	-	-	-	494	5.7	
020	14	8	86	28	01	01	19	28	44	12	-	-	-	12	13	56	-	-	-	69	0.7	
021	15	8	86	28	01	01	6	9	27	10	-	-	-	10	48	234	-	-	-	282	3.3	
022	15	8	86	28	01	01	6	15	22	10	-	-	-	10	1	93	-	-	-	94	1.3	
023	15	8	86	28	01	01	28	43	22	10	-	-	-	10	-	2	-	-	-	2	-	
024	15	8	86	28	01	01	50	56	23	10	9	-	-	19	18	355	-	-	-	373	4.6	
025	16	8	86	28	03	06	28	87	22	10	-	-	-	10	-	69	-	4	-	73	1.3	
026	16	8	86	28	03	02	22	31	22	10	-	-	-	10	6	113	-	1	-	120	1.7	
027	16	8	86	28	01	01	6	13	22	10	-	-	-	10	19	184	-	-	-	203	2.1	

Table 2 (cont'd)

Set no.	Date d	m	y	Location Area	Sub-a	Local	Depth (m) Min	Max	Soak (h)	No. of traps* P	B	M	T	Total	Prawn catch sex class (n) 0	1	2	3	4	Total	Weight (kg)
028	16	8	86	28	01	01	18	28	21	10	-	-	-	10	45	435	-	-	-	480	6.3
029	17	8	86	28	01	01	24	31	23	10	-	-	-	10	3	43	2	11	-	59	1.3
030	17	8	86	28	01	01	30	35	23	10	-	-	-	10	-	20	-	-	-	20	0.3
031	17	8	86	28	01	01	6	15	24	10	-	-	-	10	1	2	-	-	-	3	<0.1
032	17	8	86	28	01	01	7	15	24	10	-	-	-	10	9	1	-	-	-	10	0.2
033	18	8	86	28	01	01	4	9	20	10	-	-	-	10	-	-	-	-	-	-	-
034	18	8	86	28	01	01	7	7	20	10	-	-	-	10	-	-	-	-	-	-	-
035	18	8	86	28	01	01	6	9	20	10	-	-	-	10	12	2	-	-	-	14	0.2
036	18	8	86	28	01	01	2	7	20	10	-	-	-	10	-	36	-	-	-	36	0.4
Totals							2	87	916	371	49	34	4	458	249	2223	2	19	0	2493	

*P='Pardiac; B=wooden box; M=minnow; T=tube.

Table 3. ANOVA results using the carapace length of Pandalus platyceros caught as the dependent variable against depth at which caught.

	Source	df	SS	MS	F	P
A) Immature (sex class 0)	Depth	3	31.77638	10.59212	5.72	0.0009
	Error	198	366.49510	1.85098		
B) Males (sex class 1)	Depth	3	151.51977	50.50659	6.80	0.0001
	Error	1906	14150.01897	7.42393		

Table 4. Distribution difference between life history stages of some Pandalus species.

Species	Author(s)	Distribution	Notes
Pandalus borealis	Allen (1959)	N.E. England	A deep water species which likes cool, saline waters mostly between 80-650 m depth; juveniles occur in shallower water (>70 m) than adults.
	Berkley (1930)	B.C. coast	Hatch in ~90 m depth and stage III larvae migrate to ~45-65 m for their first summer, thus, juveniles are separated from adults.
	Butler (1964)	B.C. coast	Agreed with Berkley's (1930) speculation on this species life history.
	Shumway et al. (1985)	Circumboreal	Reviewed life history of the species throughout its range; females migrate to shallower waters to hatch, thus, creating differential distributions between larvae/juveniles and adults; larvae/juveniles are presumed to remain closer to shore.
P. danae	Berkley (1930)	B.C. coast	Larvae go to the bottom near where they were hatched and, therefore, show little migration.
	Butler (1964)	B.C. coast	Hatch in shallow water (~20-60 m) and generally remain in waters <80 m deep.
P. jordani	Butler (1964)	B.C. coast	No habitat notes, but adults are rarely fished in <60 m depth.
	Rothlisberg & Miller (1983)	Oregon coast	Larvae tend to be moved seaward to beds at which they were spawned.

Table 4 (cont'd)

Species	Author(s)	Distribution	Notes
P. hypsinotus	Berkley (1930)	B.C. coast	Hatch at ≈110 m and stage III lavae migrate to shallower water so that in their first summer they occur in 35-55 m after which migration occurs to deep water in winter.
	Butler (1964)	B.C. coast	Stage I-III larvae occur in same habitats as adults and metamorphosis occurs in shallower water (≈40-60 m) in their first year of life.
P. montagui	Mistakidis (1957)	W. & S. England	Migrate to inshore shallow waters, including estuaries to hatch the eggs in spring; larvae/juveniles remain inshore and then migrate to offshore in autumn; overwintering occurs offshore in cooler, saline waters; breeding population returns inshore the next spring to extrude eggs.
	Allen (1963)	N.E. England	A deep water life cycle with no inshore migration; there appears to be 2 populations in cool, saline waters resident at 40-60 m and another at 100 m.
Pandalopsis dispar	Butler (1984)	B.C. coast	Juveniles inhabit the same area as adults in deeper waters of bays and inlets but not open coast areas.

Table 5. The role of shallow-water inshore nursery areas in the life histories of some penaeid shrimp.

Species	Authors	Locality (=Lat. & Long.)	Notes
Penaeus setiferus (+5 others in less detail)	Pearson (1939)	N. Carolina south to Texas shores (=25-35°N:75-98°W)	Review of onshore migration of larvae, use of estuaries by juveniles and offshore migration to spawning grounds; stressed that the extent of nursery habitat utilization influences abundance of offshore commercial stocks.
P. setiferus P. aztecus	Williams (1955)	N. Carolina coast (34-36°N:75-78°W)	Juveniles concentrate in shallowest (=2-3 m) part of estuaries; patchy distribution according to marked preferences for channel edges, currents, muddy littered or vegetated substrates and lowered salinity.
P. setiferus P. aztecus	Zimmerman et al. (1984) Minello and Zimmerman (1985)	Galveston Bay, Texas (29°N:95°W)	Juvenile densities of P. aztecus increase significantly in salt marsh vegetation compared to bare, muddy habitats preferred by P. setiferus; innermost marsh preferred to seaward edge of marsh; experimentally demonstrated differing marsh vegetation use by different species, see also Giles and Zamora (1973).
Macropetasma africanus	Cockcroft and McLachlan (1986)	Aloga Bay, S. Africa (34°S:26°E)	Spawn offshore, larval migrate inshore, do not settle in estuaries by occupy marine 'surf zone' as juveniles prior to offshore spawning migration.
P. semisulcatus (+3 other spp.)	Hughes (1966)	E. African coast (12°-26°S)	Juveniles concentrate over intertidal sand flats and edges of mangrove stands and channels; 'organically rich' muddy substrates preferred in waters <30 cm deep.
P. semisulcatus	Tom et al. (1984)	S.E. Mediterranean (31°N:33°E)	Reviewed nursery ground use by this Indo-Pacific species; in Mediterranean late larvae congregate in tidal channels inshore and often associated with algae, juveniles shelter in shallow hypersaline lagoons with dense sea grass stands prior to the offshore spawning migration.

Table 5 (cont'd)

Species	Authors	Locality (~Lat. & Long.)	Notes
Metapenaeus dalli *P. latisulcatus*	Potter et al. (1986)	Swan estuary, W. Australia (32°S:116°E)	*M. dalli* is strictly an estuarine species for its entire life cycle. *P. latisulcatus* post larvae and juveniles use estuary as a nursery prior to offshore spawning migration.
P. esculentus	Penn and Caputo (1986)	Exmouth Gulf, W. Australia (22°S:114°E)	Juveniles occur inshore in fully saline waters; cyclones have a negative effect if they strike during inshore nursery phase through reducing salinity, wind-generated wave damage to nursery habitat, displacement of juveniles through tidal surges and coastal flooding; if cyclones occur after nursery occupation time they have a positive effect through increasing turbidity and thus, decreasing predation on migrating shrimp.
P. esculentus *P. plebejus* (+2 *Metapenaeus* spp.)	Young and Carpenter (1977) Young (1978) Coles and Greenwood (1983)	Noosa estuary and Moreton Bay, Queensland (27°S:153°E)	'All available intertidal' habitat used by juvenile penaeids; distribution related to salinity/temperature regimes, presence of seagrass, intertidal habitats; estuarine emigration predictable through changing conditions such as temperature and turbidity; destruction of nursery habitat decreases commercial offshore shrimp cyclids.
P. esculentus *P. merguiensis* (+5 other spp.)	Coles and Lee Long (1985) Staples (1985), Staples et al. (1985), Staples and Vance (1985, 1986)	Gulf of Carpentaria N. Australia (15°S:140°E)	The best understood penaeid fishery in which environmental influences on inshore life history stages are reasonably well known and commercial stocks can be predicted from monitoring such influences, mechanisms of rainfall, tide and vertical migration by which post larvae enter estuaries are known; use of seagrass, algae and mud channels by juveniles has been quantified; influences of rainfall stimulating estuarine emigration seaward by juveniles determined as single most important factor influencing offshore shrimp catches.

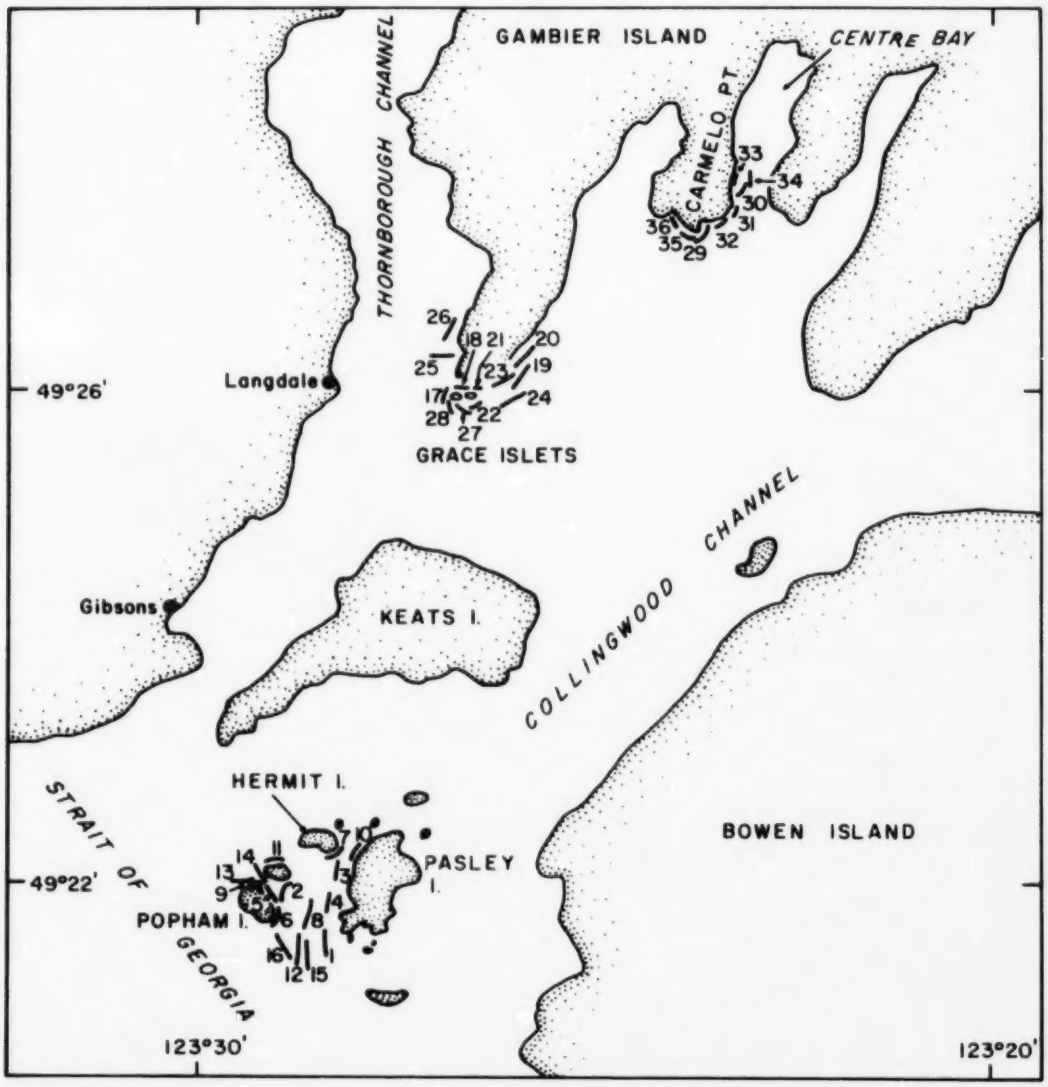

Fig. 1. Map of the mouth of Howe Sound showing the locations of the 36 juvenile prawn trap sets sampled in August 1986.

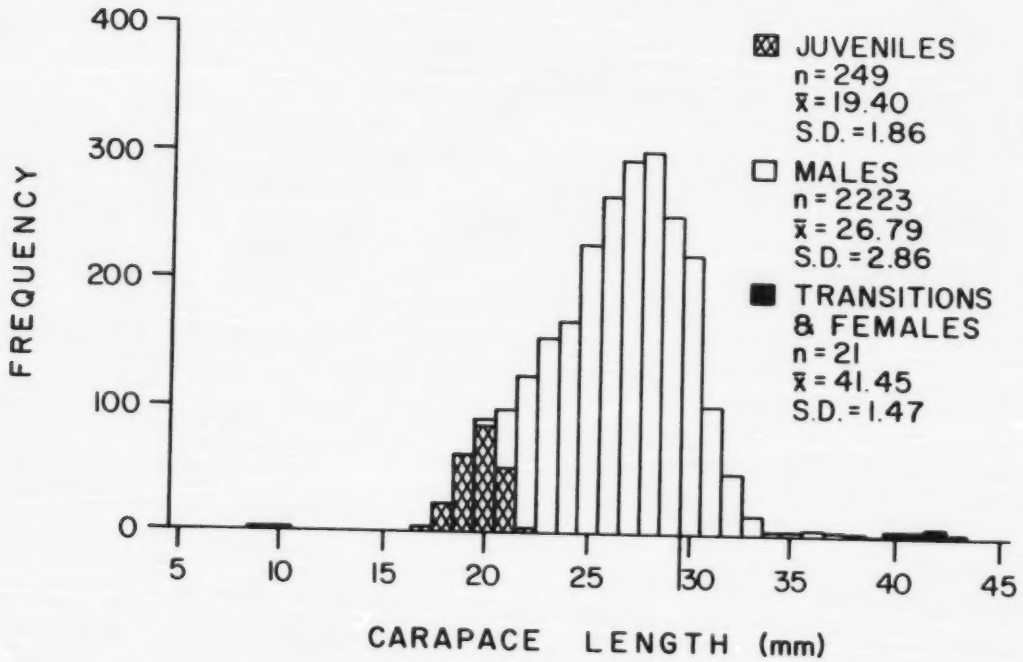

Fig. 2. Size frequency of all prawns caught in the Howe Sound survey according to sex class. Legal size of 30 mm is shown.

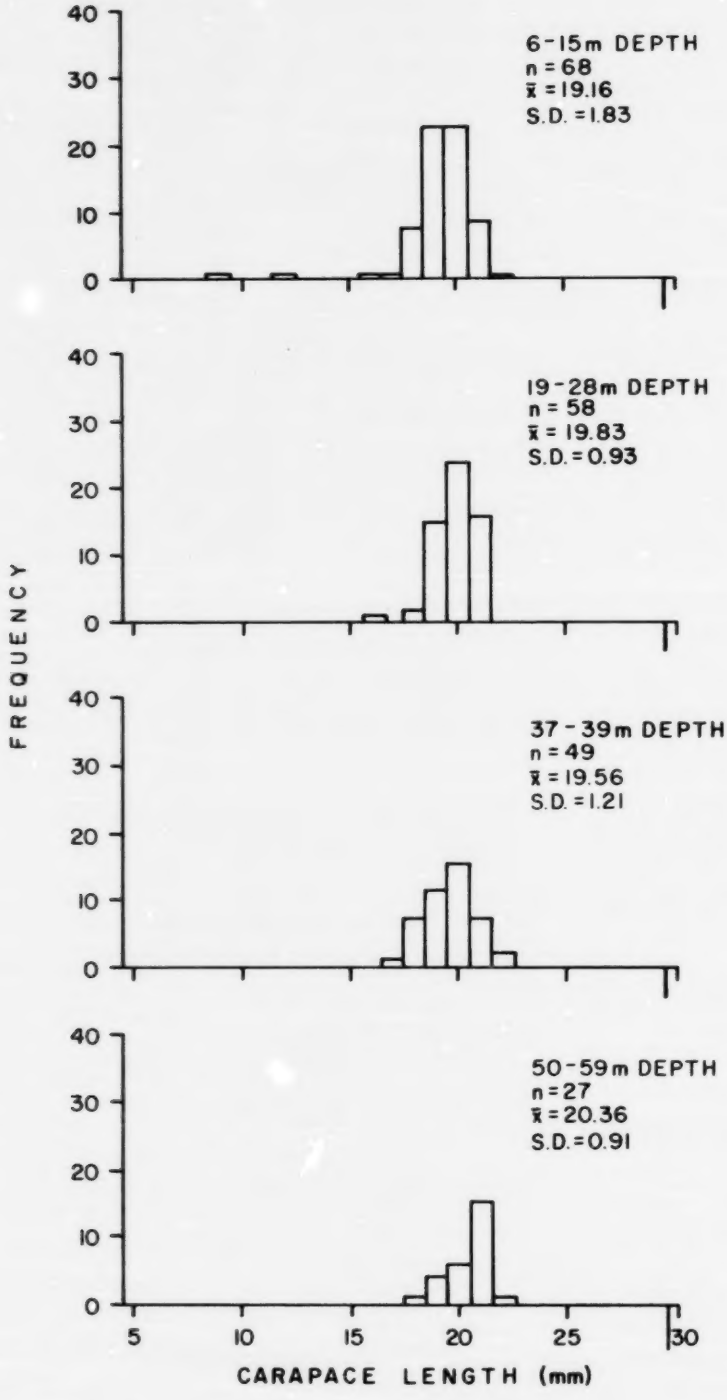

Fig. 3. Size frequencies of juvenile (sex class 0) prawns taken in sets from four depth strata in Howe Sound. Legal size of 30 mm is shown.

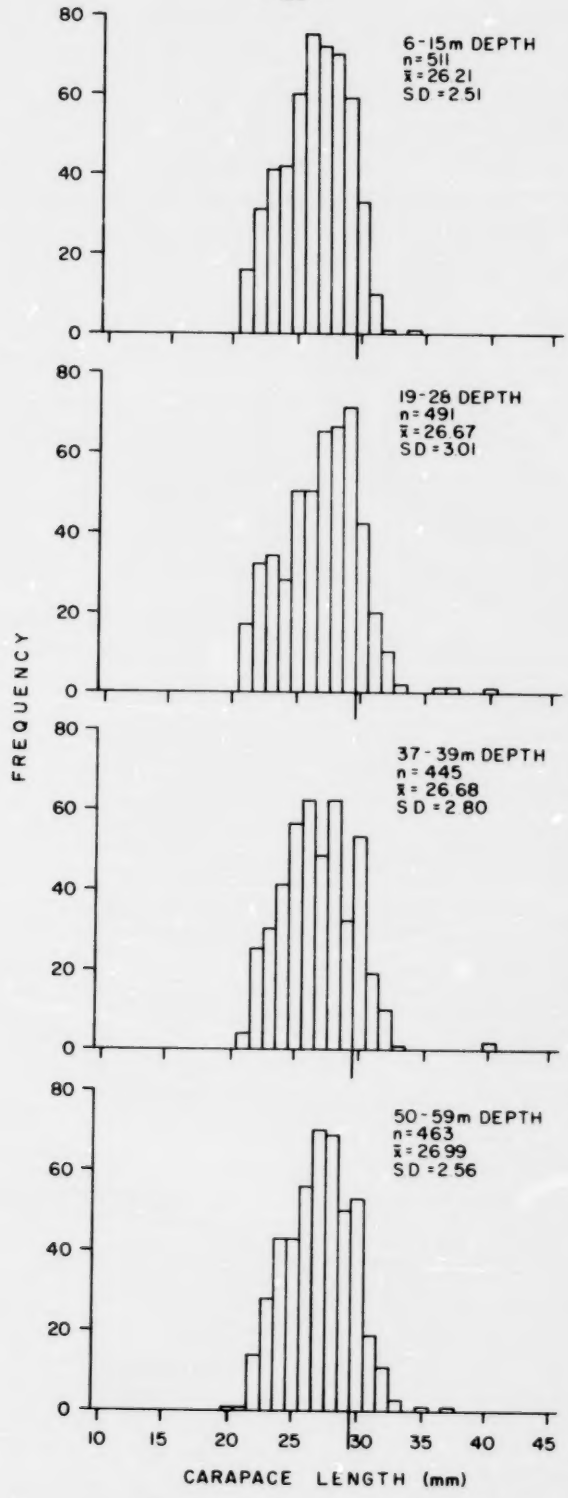

Fig. 4. Size frequencies of mature male (sex class 1) prawns taken in sets from four depth strata in Howe Sound. Legal size of 30 mm is shown.